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Study of Cosmic Ray Intensity in Association with Solar Features

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Cosmic ray intensity has been observed during the consecutive days having abnormally high diurnal amplitude and unusually low diurnal amplitude, for the period 1981-97. The High Amplitude Events (HAE) occur dominantly during the declining phase of solar activity, whereas, Low Amplitude Events (LAE) occur dominantly during minimum solar activity period. The Bz is found to remain +ve for majority of the days of the events, which shows that the occurrence of enhanced and low amplitude events is dominant during positively directed IMF polarity. The amplitude of the diurnal anisotropy increases on the day of the magnetic cloud as compared to the earlier days of the period of event and it decreases as the cloud passes the Earth. The geomagnetic activity index-Ap is found to remain low during the period of events. The majority of the events have occurred when the solar wind velocity being average or moderate, which indicates that these events are not caused during the periods of occurrence of High Speed Solar Wind Streams. The possible phenomenon to cause the enhanced as well as unusually low amplitude daily variation has been proposed to appear on the backside of the Sun.

1. Introduction

This variability is a reflection of the continually changing conditions in the interplanetary space (Fluckiger, 1991). The systematic and significant deviations in the amplitude/phase of the diurnal /semi-diurnal anisotropy from the average values (Rao, 1972) are known to occur in association with strong geomagnetic activity (Mavromichalaki, 1980). The diurnal variation might be influenced by the polarity of the magnetic field (Parker, 1991). The largest diurnal variation is observed during the days when the daily average magnetic field is directed outward from the Sun.

Three classes of clouds are identified, corresponding to the association of a cloud associated with shock (SAC), a stream interface (SI) or a cold magnetic enhancement (CME). It has been observed that the amplitude of the diurnal anisotropy is significantly larger during all the three types of clouds (Klien and Burlaga, 1982) in comparison to the amplitude observed on geo-magnetically quiet days (Yadav et al 1987). The changes have been observed in the amplitude and phase of cosmic ray intensity during high-speed solar wind streams (HSSWS) coming from coronal holes (Munakata et al., 1987).

2. Data Analysis

The anisotropic events are identified from the hourly plots of cosmic ray neutron monitor data, for 32 HAE and 27 LAE observed during 1981-97. The IMF and SWP parameters have been studied to identify the magnetic clouds during the period of events. The amplitude of the diurnal anisotropy on an annual average basis is found to be 0.4%, which has been taken as a reference line in order to select high /low amplitude events. The days having abnormally high/low amplitudes for a successive number of five or more days have been selected for study. Further, the data related with interplanetary magnetic field (IMF) and solar wind plasma (SWP) along with geomagnetic activity index Ap and Dst have been investigated. Various features, which are observed over the solar disk during the period of events, have also been looked at.

3. Results and Discussion

It has been found that the amplitude of the diurnal anisotropy for every individual high amplitude event is significantly larger than the quiet-day annual average amplitude throughout the period of investigation (Fig. 1, a) and the phase of the diurnal anisotropy has shifted to later hours for the majority of the events as compared to the annual average values (Fig. 1, b) (Kumar et al., 1993). The amplitude and phase of the diurnal anisotropy on a quiet-day annual average basis and for every individual low amplitude event have been plotted in fig.2 (a & b), which shows that the phase of the diurnal anisotropy has shifted to earlier hours as compared to quiet-day annual average values for the majority of the events (Chauhan et al, 2003).

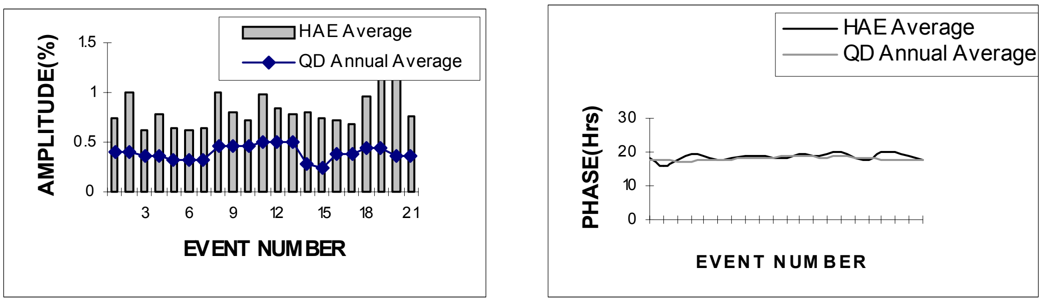


Fig.1(a) & (b)- Diurnal amplitude and phase for each HAE along with quiet day annual average values.

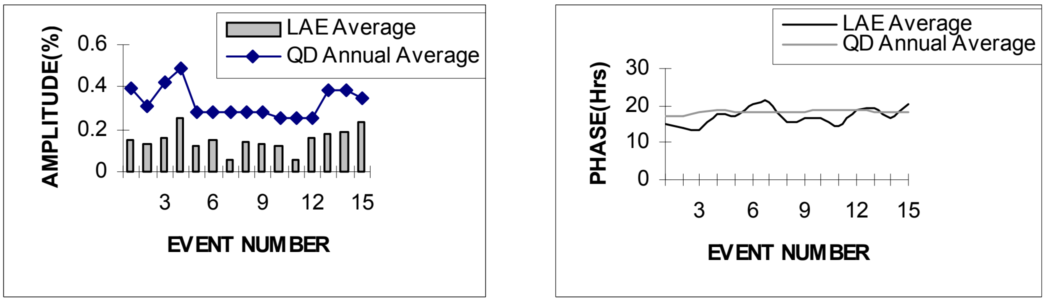


Fig.2(a) & (b)- Diurnal amplitude and phase for each LAE along with quiet day annual average values.

During the study of HAE and LAE, interplanetary magnetic clouds (Zhang and Burlaga, 1988) have been identified using the IMF and SWP parameters for each event. In fig. 3 (a & b) the amplitude and phase of the diurnal anisotropy for the HAE and LAE have been plotted during the cloud and preceding and following three days. It is quiet apparent from these plots that the amplitude of the diurnal anisotropy increases on the day of the cloud as compared to the earlier days of the period of events and it decreases as the cloud passes the Earth (Yadav et al, 1987). It is also observed that the phase of the diurnal anisotropy remains statistically in the co-rotational direction on the day of the cloud in comparison to other days of the event (Chauhan et al, 2001).

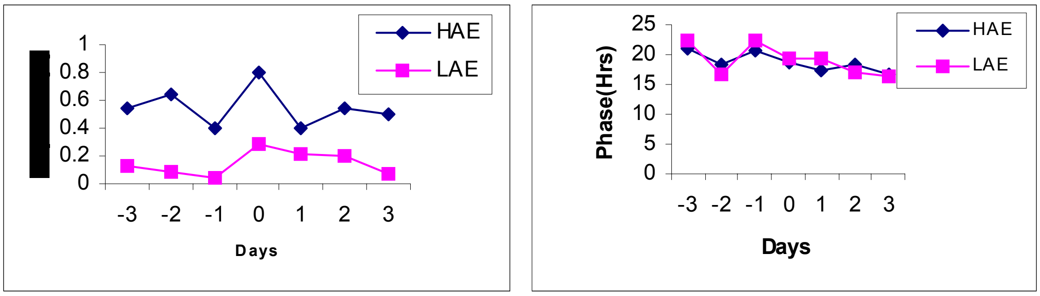


Fig.3(a) Diurnal amplitude& phase for HAE & LAE during the cloud and preceding and following 3 days.

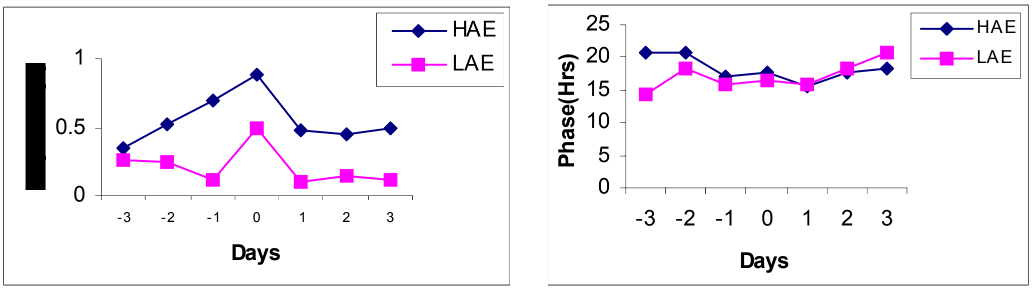
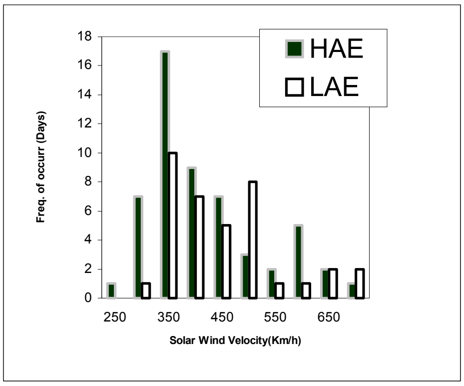


Fig.3(b) Diurnal amplitude & phase for HAE & LAE during the cloud and preceding and following 3 days.

The frequency histograms of solar wind velocity for HAE and LAE (Fig.4) shows that majority of the events have occurred when the solar wind velocity being average or moderate i.e. from 300-500 Km/Sec. This shows that these events are not caused during the periods of occurrence of HSSWS (Munakata et al, 1987).



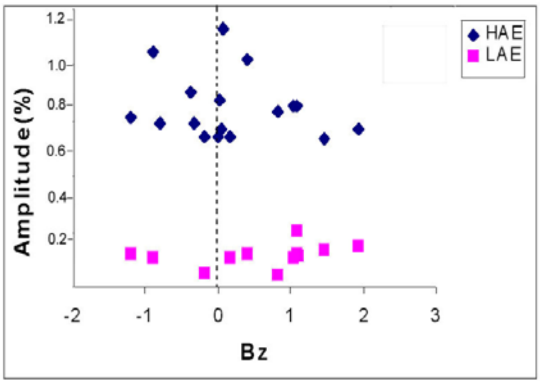


Fig.4 Freq. Histogram of solar wind velocity. **Fig.5 -** Amplitude of the each HAE & LAE with Bz

Further, the z/t-test for distribution of solar wind velocity for three groups of days (high amplitude, low amplitude and quiet days) have been investigated for their significance (Chauhan et al, 2001). It was found that the lowest range of value of solar wind velocity is observed for low amplitude events, whereas slightly higher range is observed for high amplitude events. Further, the increase in solar wind velocity ranges has been found for quiet days, however, the z/t-test does not differentiate between the three groups of days. The significance is pronounced even at the 1% level in case of low amplitude evens and quiet-days.

The amplitude and phase of the diurnal anisotropy for each high/low amplitude events has been plotted with the variation in associated values of the Z-component of the IMF, i.e., Bz in Fig.5.The Bz is found to remain +ve for the majority of the days of the events of high/low amplitude events, which shows that the occurrence of these events is dominant during the positively directed IMF polarity (Chauhan et al, 2003). Further, the geomagnetic activity indexes Ap on an average basis remain low during the period of each event. This may be because the interplanetary disturbances responsible for cosmic ray modulation effects have not reached the Earth. The solar activity on the backside is not likely to produce the usual terrestrial manifestations such as geomagnetic storms, produced by activity on the visible side of the Sun. However, modulation by plasma clouds ejected from the backside and the subsequent propagation of cosmic ray particles might reveal such flare activity. If this is so, these events in the absence of geomagnetic storms/Forbush decreases may be used to infer the presence of solar activity on the hidden side of the Sun.

4. Conclusions

The amplitude of the diurnal anisotropy increases on the day of the cloud as compared to the earlier days of the period of HAE and LAE and it decreases as the cloud passes the Earth. The phase of the diurnal anisotropy remains statistically in the corotational direction on the day of the cloud in comparison to other days of the event. The occurrence of high/low amplitude events is dominant during the positively directed Bz-component of IMF polarity. The high amplitude events have occurred dominantly during the declining phase of solar activity, whereas the low amplitude events are more dominant during the period of minimum solar activity. The geomagnetic activity index, Ap, has been observed to remain low during the period of these events.

Thus, one may conclude that the interplanetary turbulences responsible for cosmic ray modulation effects do not reach the Earth and the possible sources to cause the high/low amplitude events may be due to the intense solar activity on the backside of the Sun.

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